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ORIGINAL RESEARCH

Pet rat welfare in the United Kingdom: The good, the bad and the ugly

Vikki Neville[1] | **Jessica Mounty**[1] | **Livia Benato**[1,2] | **Kristina Hunter**[2] | **Michael Mendl**[1] | **Elizabeth S Paul**[1]

[1] Bristol Veterinary School, University of Bristol, Bristol, UK

[2] City Vets, Exeter, UK

Correspondence
Vikki Neville, Bristol Veterinary School, University of Bristol, Bristol, BS40 5DU, UK.
Email: vikki.neville@bristol.ac.uk

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Abstract

Background: To date, despite the substantial literature investigating how rats prefer to be kept in captivity, no research has been conducted to assess the housing, husbandry and health of pet rats.

Methods: To better understand the United Kingdom's pet rat population and the welfare issues they face, we conducted an online survey of pet rat owners. The survey included questions about the owner and their opinions about pet rats, and about their rats' health, husbandry and housing.

Results: The results, from 677 complete responses, highlighted areas of rat care that were "good", "bad" and "ugly" (i.e. likely to be highly detrimental to welfare). The good was that many rats were provided with a social companion and enrichment; the bad was that we could not be certain whether rats had a sufficiently nutritious diet or sufficient opportunities to explore or adequate nesting substrate; and the ugly included cases of exposure of rats to predator species within the home and a generally high prevalence of disease.

Conclusions: We conclude that there is much cause for concern about the welfare of pet rats in the United Kingdom.

INTRODUCTION

The plethora of studies investigating rat (specifically, *Rattus norvegicus*) ecology and laboratory rat welfare have taught us much about how rats should be cared for in captivity. These studies have highlighted the importance of opportunities for digging and nesting,[1–5] the importance of conspecific companionship[1,6–7] and the importance of complex and enriching environments.[8,9] Previous research has also demonstrated that exposure to predator species is stressful to rats[10–14] and that, as a prey species, opportunities to hide and shelter are of great importance to rats.[1,3,15] This evidence has informed the current guidelines on pet rat care provided by the PDSA and RSPCA.[16,17]

In 2020, there were an estimated 100,000 rats kept as pets in the UK.[18] However, we do not know whether, or to what extent, existing findings about the needs and stressors of rats have filtered through to owners of pet rats. Moreover, pet rats do not require vaccinations or microchipping and so may not be seen by veterinary professionals who could provide guidance about rat care – making their welfare a particular concern. Yet, to date, there has been no published research into the current state of housing and husbandry of pet rats in the United Kingdom or elsewhere.

A common approach to researching the welfare conditions of companion animals is to survey owners and ask them to report on the housing and husbandry of their companion animal.[19–25] Previous research using this approach has been very fruitful; it has identified dietary issues in guinea pigs and rabbits,[19–21] poor standards of housing in rabbits,[20,22] and that the level of exercise of many dogs is insufficient.[23] Although one limitation of surveys is that only pet owners who are particularly enthusiastic about their pets may respond, leading to a participation bias.

The aim of this study was to survey owners about the housing, husbandry and health of pet rats in the United Kingdom in order to identify

potential welfare issues. In particular, we hoped to identify areas in which rat care is in line with or exceeds recommendations ("the good"), areas that are a potential welfare concern ("the bad"), and areas that are likely to be highly detrimental to the welfare of pet rats ("the ugly"; where the five freedoms[26] are not met). This will allow a more targeted approach for efforts to educate potential and current owners of pet rats, and hence maximise welfare improvements.

METHODS

The survey was created using Google Forms and was distributed via social media – including Twitter, Reddit, and Facebook, as well as through word of mouth. It was "live" for a three-week period from 25 August 2020 to 15 September 2020. Respondents were all over the age of 18 and resided in the United Kingdom; their participation in the study was voluntary, and they provided informed consent before completing the survey. There was no incentive offered for participation in the survey. This study received ethical approval from the Faculty of Science Ethics Committee at the University of Bristol (reference number: 103082).

Survey contents

The survey was designed to take approximately 5 to 15 min to complete, and comprised seven sections: (a) You and your rat(s); (b) Your rat(s); (c) Your rat's/rats' cage(s); (d) Interacting with your rat(s); (e) Your rat's/rats' health; (f) Your experience as a rat owner; and (g) Your rat's/rats' behaviour. Table 1 details the questions asked in each category (excluding the behavioural questions which were analysed separately to this study; see Supporting Information 1). The questions were a mix of those that required a response to be entered (text or numeric), checkboxes (allowing multiple responses to be selected), and multiple choice (only one response selected). For all non-exhaustive and relevant checkbox or multiple-choice questions, there was an 'other' option which allowed the respondent to enter a response that had not been listed. Options provided in the multiple-choice or checkbox questions are detailed in Supporting Information 2. Some questions were only shown to the respondents to whom they were relevant, based on their previous answers. For example questions about the age of the oldest and youngest rat were not shown to owners reporting that they only had one rat. The third section, 'Your rats' cage' could be answered multiple times for different cages.

Data analysis

Relevant data were extracted from the survey responses (see Supporting Information3); descriptive statistics (median and percentages) were calculated, and inferential statistics (binomial test and logistic regression) were conducted in R.[27] To assess whether there were sex or age differences in the likelihood that a specific health issue, symptom, or veterinary visit was reported, we fitted logistic regression models to each of these (binomial: 1 = reported, 0 = not reported) using sex of rats owned (male, female, both), age group category selected by the respondent (1, 0–6 months; 2, 6–12 months; 3, 1-1.5 years; 4, 1.5-2 years; 5, 2-2.5 years; 6, 2.5-3 years; alf7 - more than 3 years), and total number of rats as predictor variables. As there were overlapping categories for age, there may be some instances where more than one category would be appropriate (e.g. either category 1 or 2 could be selected for a rat that was exactly 6 months old, and either category 3 or 4 could be selected for rat that was exactly 1.5 years old). However, the ordinal structure of the age groups still stands; a respondent that selected category 3 would always have an older rat than an owner that selected category 1. Given that geriatric rats are prone to a number of diseases[28] and that the likelihood of observing a particular disease increases with the number of rats owned, we hypothesised that respondents with older rats and a larger number of rats would be more likely to report each health issue. We did not anticipate any sex differences. Additionally, to test the hypothesis that respiratory problems were more common where a dusty substrate had been used or the rats' cage was cleaned less frequently, substrate dustiness (1 = dusty subtract used, 0 = no dusty substrate used) and cleaning frequency (coded as follows: 1 - daily; 2 - between daily and weekly; 3 - between weekly and fortnightly; 4 - between fortnightly and monthly; 5 - less than once per month) were added as predictor variables to the logistic regression of respiratory issues. Finally, we also tested for the possibility that dental problems may depend on the food type by including food type (home-made; home-made including commercial mix; shop-bought muesli; shop-bought nuggets) as a predictor variable in the logistic regression of dental issues.

Likelihood ratio tests were used to assess the significance of each predictor variable. All p-values were adjusted using the false discovery rate,[29] using the p.adjust function in the R stats package, due to the large number of statistical tests being conducted simultaneously. This function takes p-values and adjusts them upwards according to the false discovery rate. For example, the following set of p-values: 0.050, 0.800 and 0.010, would have the following adjusted p-values: 0.075, 0.800 and 0.030.

RESULTS

The owners, their rats and their opinions about rats

A total of 677 questionnaires were completed in full. Respondents reported living in households with a median of two adults, earning a median income of £35,000, and having a median of zero children (67.9% had no children, 13.1% had one, and 18.9% had two or

TABLE 1 Summary of the survey contents including the survey sections, questions within those sections, response type, and whether the presentation of the question depended on the respondent's prior responses

Section	Question	Response type	Dependent on previous response?
1. You and your rat(s)	How many adults live in your household?	Numeric	
	How many children live in your household?	Numeric	
	What is your gross annual income in £?	Numeric	
	Do you have any other pets?	Checkbox	
	Do your other pets, if any, spend any time in the same room in which the rat(s) are housed?	Checkbox	
	How many rat(s) do you currently own?	Multiple choice	
2. Your rat(s)	What is the sex of your rat?	Multiple choice	Owns only one rat.
	How many female rats do you own?	Numeric	Owns more than one rat.
	How many male rats do you own?	Numeric	Owns more than one rat.
	What is the age of your rat?	Multiple choice	Owns only one rat.
	What is the age of your youngest rat?	Multiple choice	Owns more than one rat.
	What is the age of your oldest rat?	Multiple choice	Owns more than one rat.
	Since you have owned your rat, have they ever been housed with another rat (e.g., who was rehomed or passed away)?	Multiple choice	Owns more than one rat.
	Where did you obtain your rat(s)?	Checkbox	
	How many different groups (i.e. that do not live together) of rats do you have?	Numeric	Owns more than one rat.
3. Your rat's/rats' cage	Which of the following items are in your rat's/rats' cage?	Checkbox	
	What type of bedding/nesting material do you use in the cage?	Checkbox	
	What do you feed your rat?	Checkbox	
	What food do you give to your rat as a treat, if any?	Text	
4. Interacting with your rat(s)	How often do you handle your rat(s)?	Multiple choice	
	How often do you clean your rat's/rats' cage?	Multiple choice	
	Which of the following applies to you and your rat(s)?	Checkbox	
5. Your rat's/rats' health	Have you ever taken your rat(s) to the vet?	Multiple choice	
	Have your rat(s) been diagnosed with or shown any of the following health conditions/signs of health conditions?	Checkbox	
6. Your experience as a rat owner	Would you recommend rats as pets?	Multiple choice	
	What do you like/dislike about rats?	Text	
	Please feel free to use this space to tell us anything about your rats that youfeel is relevant!	Text	

more). The majority of owners (61.4%) reported having another pet. Over a quarter of the 677 respondents (29.1%) reported owning a predator species whose odour is known to induce fear in rats in a laboratory setting[10–14] (i.e. cat, ferret or snake), and 60.4% of these respondents reported that this pet had access to, or were housed in, the room in which the rats were kept. If we include dogs, who could predate rats, although there is currently no evidence as to whether or not the odour of dogs induces fear in rats, this rises to 47.7% of owners reporting owning a predator species, with 68.4% of these owners allowing a predator species access to the same room in which the rats were housed.

In total there were 3893 rats owned across all participants (i.e. ~3.9% of the UK's estimated pet rat population[18]). The majority of respondents (97.6%) owned more than one rat, with the respondents owning a median of four rats. Of the respondents who reported owning only one rat, 81.3% reported that their rat had previously been housed with another rat (e.g. the rat had previously been kept in a group or pair, but the other animals had now died). Respondents more commonly reported owning only male rats (43.6%) than only female rats (36.0%), and 19.9% of respondents owned both male and female rats (Figure 1). The bias towards owning male rats was significant according to an exact binomial test (244 female-only groups out of 539 single sex groups, $p = 0.031$). The median age group for rats was 1.5-2 years, with very few respondents reporting owning a rat over the age of three years (1.79%) (Figure 1).

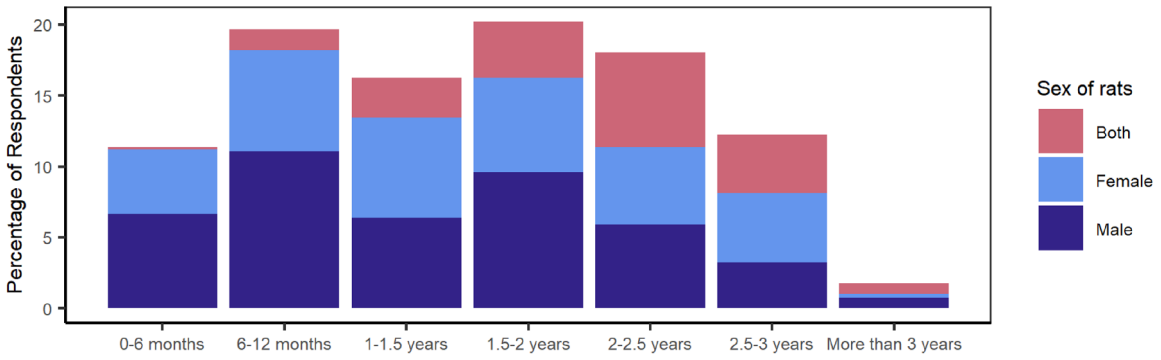

FIGURE 1 Distribution of the age of respondent's oldest rat and distribution of sex within each age category; each bar represents the percentage of respondents whose oldest rat was within each age-group category

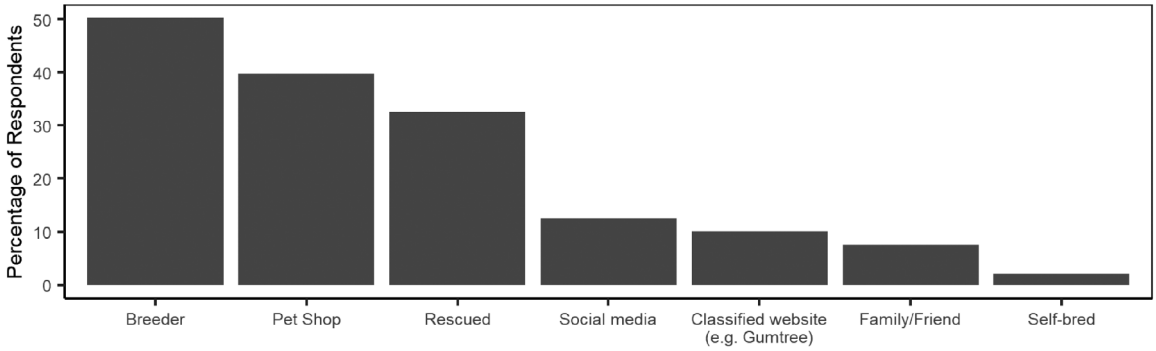

FIGURE 2 The popularity of different suppliers of pet rats: each bar represents the percentage of respondents who obtained at least one rat from each potential supplier of pet rats. As many respondents owned more than one rat and may have sourced each rat from a different supplier, the percentages shown here will not total 100%

Rats were most commonly obtained from a breeder, with 50.2% of respondents reporting that at least one of their rats was bought directly from a breeder. Over a quarter of respondents reported that at least one of their rats was bought from a pet shop (39.7%) or had been obtained from a rescue centre or other rehoming organisation (32.5%) (Figure 2).

Almost all owners (99.1%) said that they would recommend rats as pets, and 83.3% reported liking one or more things about their rats. When describing these liked characteristics, respondents frequently reported liking the intelligence of rats (46.1%), and also commonly reported liking aspects of the relationship they felt their rats had with them (e.g., the friendliness (30.3%) and affectionate nature of rats (32.8%), and their general interactions (21.8%; Figure 3a)). They also reported that they liked that rats were entertaining (24.8%). Only 41.1% of respondents reported disliking something about pet rats. The respondents that included a 'dislike' most commonly reported that they disliked the short lifespan of rats (52.1%; Figure 3b). They also commonly reported disliking the smell of rats (26.3%) and their proneness to health issues (20.5%).

The rats' housing and husbandry

Nearly all respondents reporting using bedding or nesting material in their rats' cage (99.0%) with each respondent using a median of three different types of material. The most popular bedding/nesting substrate was paper pellets (53.6%), although several other substrates were commonly reported such as cardboard (36.8%), fleece (33.7%), sawdust/wood shaving (32.8%), and tissue (29.2%) (see Figure 4). Over a third of respondents (38.5%) reported using a potentially dusty substrate, such as sawdust (see Supplementary Material 2 for full list). Bedding and nesting substrates may serve several purposes[17]; while they can cover the floor to absorb urine, they can also be used to provide rats with an opportunity to engage in natural behaviours such as digging and nesting. A majority (87.0%) of respondents reported using a substrate that could unambiguously provide an opportunity for digging, such as paper pellets (see Supplementary Material 2 for full list), while 64.6% reported using a substrate that could unambiguously be used for building nests, such as tissue (see Supplementary Material 2 for full list).

All categories of enrichment items were included in the rats' cage by the majority of respondents; suspended area (99.0%), climbing structure (96.8%), hideaway (94.2%), tubes (78.9%), foraging toy (66.8%). The majority of respondents also provided activities for their rats (87.4%), for example provided access to a tank for digging or foraging opportunities such as fishing for food in water. However, very few respondents allowed their rat time to run freely outside of their cage (2.36%), had a separate playpen for their rats (0.6%), or trained their rats to perform tricks (0.30%).

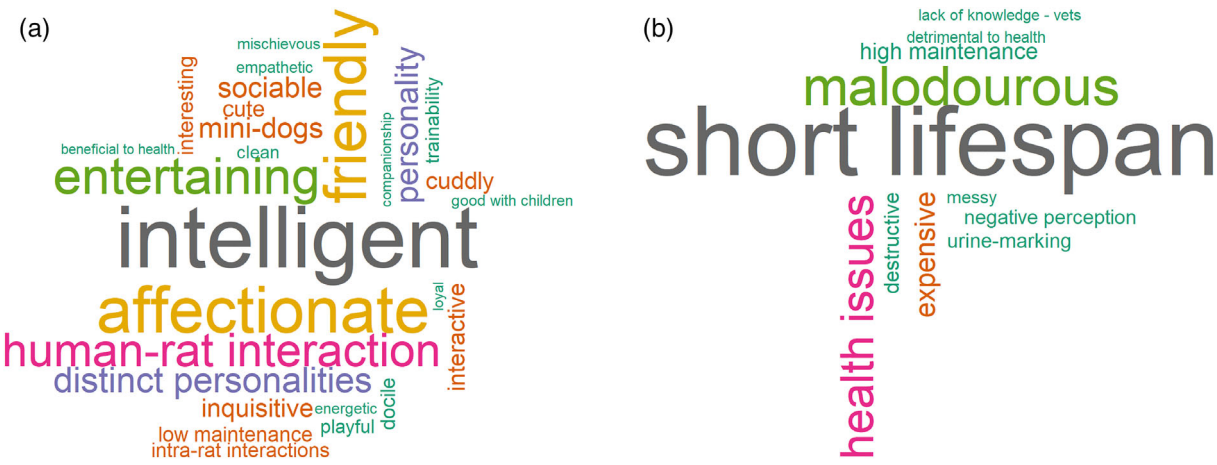

FIGURE 3 (a,b) The frequency of rat (a) likes and (b) dislikes reported by rat owners; larger font indicates more frequent reporting

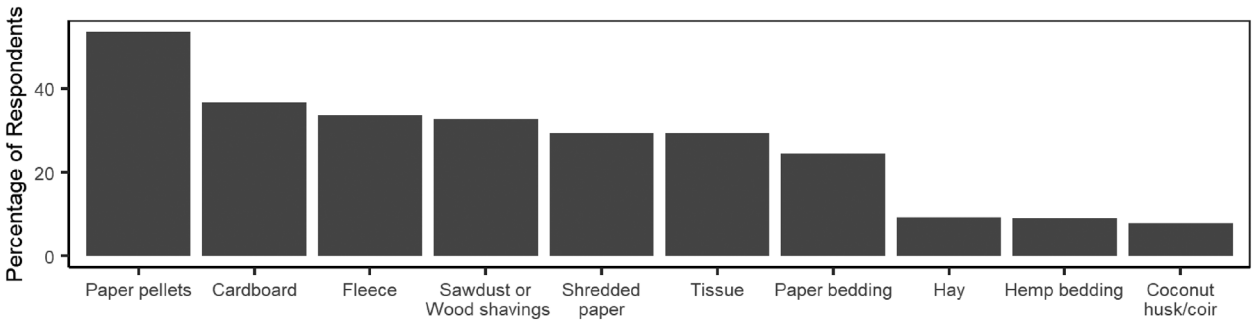

FIGURE 4 The ten most popular bedding and nesting substrates: each bar represents the percentage of respondents who used each potential substrate in their rat's/rats' cage

Most respondents (91.6%) handled their rats daily, and the most common cleaning frequency was between weekly and fortnightly (44.0%).

Rats were most commonly (39.4%) fed a home-made rat food, close to a quarter of respondents fed their rat(s) shop-bought nuggets (26.3%) or muesli (24.2%), and the remaining respondents (10.6%) reporting using a home-made mix that incorporated a commercial food mix. A wide range of food treats were reported by respondents, but the most common were non-specific fruit (37.9%) and non-specific vegetables (29.0%), eggs (13.6%), malt paste (13.4%), pasta (11.6%) and chicken (11.5%). Other less popular treats included banana (9.7%), nuts (9.4%), mealworms (7.0%), baby food (7.8%), dog treats (7.5%), and chocolate (6.9%).

The rats' health

A minority of respondents (21.0%) reported never having taken their rat(s) to the vet. The majority (60.4%) reported respiratory issues in their rats. Tumours (36.6%), abscesses/cysts (31.2%), hind leg degeneration (25.0%), external parasites (20.5%), and head tilt (15.2%), were also commonly reported. Less commonly reported issues were cardiac disease (8.27%), dental problems (6.6%) genital disease (5.5%), limb problems (5.2%) and ulcerative pododermatitis (1.5%) (Figures 5 and 6). Chromodacryorrhea[30] (secretion of "red tears") was reported by 39.7% of owners.

In line with our hypotheses, the majority of health-related variables included in the survey were significantly more likely to be observed in older rats (Table 2, Figure 5). There were also several health issues that were significantly more likely to be reported if the respondent had a larger number of rats: abscesses/cysts, head tilt, hind leg degeneration, respiratory issues, tumours (Table 2). The analysis of health issues also revealed that owners of female rats were more likely to report tumours in their rats, while owners of male rats were more likely to report abscesses or cysts in their rats (Table 2, Figure 6). We found no evidence that respiratory issues were associated with the use of a dusty substrate or cleaning frequency, or that dental problems were associated with food type (Table 2). Results of statistical analyses are shown in Table 2.

DISCUSSION

While much research has been conducted to understand the needs and stressors of rats in captivity, little is known about whether this has been successfully conveyed to owners of pet rats. The aim of this study was to gain insight into rat housing, husbandry, and health in the United Kingdom by surveying pet

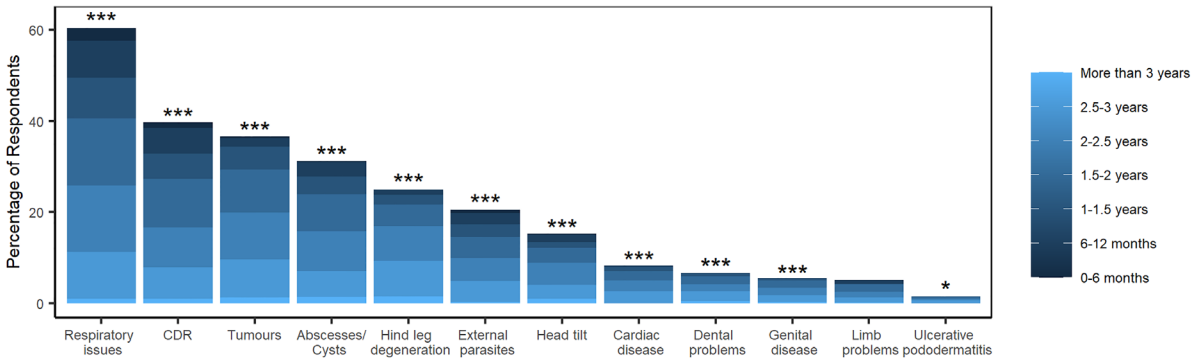

FIGURE 5 The frequency at which different health issues or symptoms of them were observed by the owners split by the age of the rats: each bar represents the percentage of respondents reporting have observed an issue/symptom in their rat(s) with colours representing the proportion of each age group within each health issue or symptom. CDR is an abbreviation of chromodacryorrhea. The number of asterisks indicates the level of significance of age as a predictor of each health issue or symptom (*p < 0.05, **p < 0.005, and ***p < 0.001)

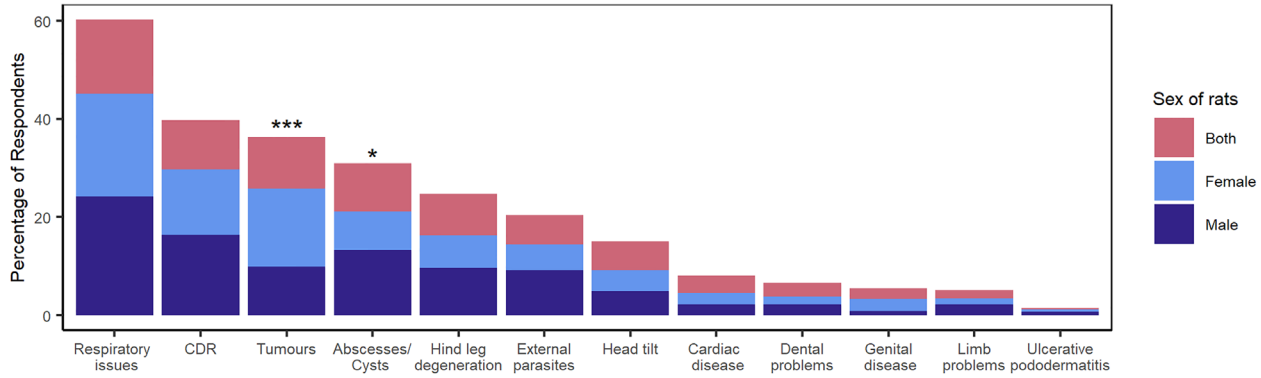

FIGURE 6 The frequency at which different health issues or symptoms of them were observed by the owners split by the sex of the rats: each bar represents the percentage of respondents reporting have observed an issue/symptom in their rat(s) with colours representing the proportion of each sex within each health issue or symptom. The number of asterisks indicates the level of significance of sex as a predictor of each health issue or symptom (*p < 0.05, **p < 0.005, and ***p < 0.001)

rat owners, which would allow identification of any potential welfare issues. Here, we outline aspects of pet rat care, as informed by the survey data, that we consider to currently be "good" (in line or exceeds guidance), "bad" (a potential welfare concern) and "ugly" (likely very detrimental to the welfare of rats, and where the five freedoms[25] are not met). We also discuss limitations to this survey and potential actions to be taken to remedy the bad and the ugly aspects of current pet rat care.

The good

The social needs of rats were largely being met; nearly all rats were housed with a conspecific, and in the few cases where rats were housed singly, they had most typically been previously housed with another rat (e.g. who died). Rats were also typically provided with multiple enrichment items, including areas to hide and substrate which would provide a digging opportunity (although it is unclear whether the substrate would have been deep enough to allow burrowing).

The strong bond between owners and their rats was also clear from the survey results: Owners commonly reported that they found rats to be affectionate and liked their interactions with their rats, and frequently reported that they disliked the short lifespan of rats. Moreover, nearly all owners reported that they typically handled their rats daily; this contrasts with a studies of pet rabbits and guinea pigs where lower handling frequencies are reported (57.5% of owners report handling their guinea pig daily[19]; 46.3% of owners report handling their rabbit daily[22]).

The bad

It is unclear from the survey data whether the nutritional needs of rats are being met; over a third of owners used a home-made feed for their rats, and we cannot determine whether these diets would supply all necessary nutrients. Likewise, it is unclear whether the rats obtained from a breeder (which was the most popular supplier of rats) or a pet shop were bred responsibly with the breeding rats living in suitable conditions, and the pups weaned at an appropriate age. Indeed, there is currently no legislation to regulate the breeding of pet rats (as there is for dogs, although no other companion species; The Animal

TABLE 2 Results of the statistical analyses of the impact of age, sex, total number of rats (Total N^o rats) owned by the participant, hygiene related variables (respiratory problems only), food type (dental issues only) on health issues, symptoms, and whether a veterinarian had been visited. The number of asterisks indicates the level of significance (*p < 0.05, **p < 0.005, and ***p < 0.001)

Model	Variable	LRT (Likelihood ratio test) value	Adjusted p-Value	Significance level
Abscesses/Cysts	Age	57.289	<0.001	***
	Sex	11.868	0.021	*
	Total N^o rats	11.632	0.002	**
Cardiac disease	Age	17.216	<0.001	***
	Sex	3.354	0.461	
	Total N^o rats	4.181	0.082	
Chromodacryorrhea	Age	39.880	<0.001	***
	Sex	4.208	0.347	
	Total N^o rats	1.299	0.356	
Dental problems	Age	23.141	<0.001	***
	Food	2.286	0.776	
	Sex	1.103	0.802	
	Total N^o rats	3.712	0.099	
External parasites	Age	20.157	<0.001	***
	Sex	5.703	0.190	
	Total N^o rats	3.986	0.088	
Genital disease	Age	18.3212	<0.001	***
	Sex	7.416	0.105	
	Total N^o rats	0.1402	0.783	
Head tilt	Age	27.1428	<0.001	***
	Sex	2.6578	0.569	
	Total N^o rats	5.6068	0.042	*
Hind leg degeneration	Age	138.259	<0.001	***
	Sex	6.737	0.130	
	Total N^o rats	5.375	0.045	*
Limb problems	Age	4.3978	0.076	
	Sex	1.8925	0.694	
	Total N^o rats	3.2493	0.120	
Respiratory	Age	68.671	<0.001	***
	Cleaning frequency	8.052	0.140	
	Dusty substrate used	0.378	0.646	
	Sex	0.714	0.870	
	Total N^o rats	6.324	0.029	*
Tumours	Age	114.659	<0.001	***
	Sex	25.653	<0.001	***
	Total N^o rats	8.559	<0.001	*
Ulcerative pododermatitis	Age	8.512	0.011	*
	Sex	1.144	0.802	
	Total N^o rats	0.076	0.802	
Veterinarian visited	Age	120.925	<0.001	***
	Sex	2.304	0.632	
	Total N^o rats	0.8	0.487	

Welfare (Licensing of Activities Involving Animals) (England) Regulations 2018). Worryingly, there was a significant bias for ownership of male rats – which, assuming that this arises at the point of acquisition, raises the question of what is happening to unwanted female rats that may be more difficult to sell.

Owners rarely provided their rats with an opportunity to explore outside of their cage (either freely or in a separate playpen). The home range for wild Brown rats has been found to a minimum of ~30 m in diameter, with wild rats travelling a minimum of 10 m per day.[30] This would suggest that movements of pet

rats are very much restricted in comparison to their wild counterparts. However, the extent to which this may be detrimental to the welfare of rats is unknown.

Although nearly all respondents provided their rat with a shelter, which would have provided rats with a necessary dark area in which they could hide and rest, over a third of respondents did not provide their rats with a substrate that could unambiguously be used for nesting. Nesting is highly important to rats and they have been shown to prefer cages that include suitable nesting material over those that do not (although they also show a preference for nest boxes over nesting materials).[3–5] Nesting materials allow rats to regulate their body temperature and perform natural nesting behaviours.[1,32] However, it is unclear whether alternative means of regulating body temperature, such as sleeping in close proximity to cage-mates, or ready-made nests, such as fleecy nesting hammocks may obviate the need for nesting materials to ensure good welfare. Without inspecting each cage, we also cannot be certain whether more ambiguous substrates (e.g. cardboard or fleece, which could either be shredded to provide nesting material, or provided just as a sheet) would have provided suitable nesting material. Likewise, despite including common brands names, we cannot be certain that paper pellets (not at nesting material) were not confused with paper bedding or paper wool (both nesting materials). Thus, while the lack of suitable nesting material (e.g. tissue, shredded paper, paper wool) may be highly detrimental to the welfare of rats, more research needs to be conducted to assess the substrates, environmental factors, and potential enrichment items that would allow rats' nesting requirements to be fully met.

The ugly

The study revealed that the basic needs and freedoms of many rats were not being met. In particular, over a third of rats lived in close proximity to predator species (cats, dogs, ferrets, snakes that have access to same room that rats are kept in). Given that predator odours can induce a stress response in rats (at least in a laboratory setting)[10–14] and there is conflicting evidence as to whether laboratory rats habituate to predator odours,[14,33–35] it is possible that these pet rats are not free from fear and distress – a core aspect of welfare.

Health issues were highly prevalent in pet rats, although more so in older rats. In particular, respiratory issues were reported by a majority of owners. While this finding might reflect that many (> 90%[36]) pet rats will carry mycoplasma which causes such issues and is difficult to control or eliminate,[36] the environment and diet of the rat has been shown to contribute to disease outcome.[36] In particular, increased ammonia levels, poor ventilation, pine and cedar bedding substrate, and nutritional deficiencies have been associated with poorer disease outcome.[36] Although the total number of rats was a predictor of respiratory issues, it is unclear whether this directly relates to the rats' environment (e.g. a greater number of rats leading to a greater build-up of ammonia and hence a greater likelihood of respiratory issues) or the likelihood of a health issue occurring in at least one rat (e.g. the probability of at least one rat in a group of six developing a respiratory issue is greater than the probability of at least one in a group of three developing a respiratory issue).

Many owners used a potentially dusty substrate (i.e. sawdust, wood shavings, hay, straw, or cat litter) in the cage which may irritate the rats' respiratory system – although we found no evidence that use of a dusty substrate was associated with a greater incidence of respiratory issues. In addition, owners most frequently cleaned their rats' cage between weekly and fortnightly – which may be insufficient to avoid the build-up of ammonia, depending on the size of the cage and ventilation. Again, however, we found no evidence that cleaning frequency predicted the likelihood of respiratory issues. Nevertheless, it may be the case that there are a combination of other environmental factors contributing to respiratory issues, including those that were not recorded here such as cage space per rat, degree of ventilation, number of air changes in the room, or whether the respondent was a smoker. Thus, it is possible that in some cases the respiratory issues were preventable. Similarly, almost 40% of participants reported observing chromodacryorrhea (described in the survey as 'Porphyrin secretions i.e. red staining around eyes/nose') in their rats, which is considered to be a sign of poor health or stress.[30,37,38] While this may result from unpreventable health issues (including old age – see Table 2), it might also sometimes reflect preventable causes of poor health or stress such as an unsuitable environment or poor diet.[28,30,36–38]

The finding that owners of female rats were more likely to report observing tumours in their rats may reflect the high incidence of mammary tumours in female rats[28]; ovariectomy in the juvenile rat may reduce the likelihood that they later develop mammary tumours, although this will carry its own risks.[39,40] Owners of male rats were more likely to report observing abscesses or cysts in their rats. Although we can't be certain of the aetiology of these, it is plausible that some of these may have resulted from fight wounds. If this were the case, then it would suggest that action should be taken by owners to reduce aggression among their male rats. Husbandry modifications (e.g. separation into smaller groups, ensuring that food, water and shelter cannot be monopolised) and castration[41] may be able to reduce male-male aggression to ensure that such injuries do not occur and to reduce the stress associated with fighting,[42–44] although further research is needed to determine the most effective interventions.

The present results need to be interpreted in the context of a likely participation bias which has been reported as a limitation in similar studies.[24,25] The respondents may not be entirely representative of the average pet rat owner in the United Kingdom. Indeed, the low incidence of respondents with children sug-

gests that we did not reach many people who had children with pet rats, which is likely to be common.[45] Our survey may have only reached people who were particularly enthusiastic about pet rats, and who had a lot of time available to spend with them. If this is the case, then our data may represent a best-case scenario for the welfare of pet rats. Thus, the 'good' may be only be applicable to a relatively small subset of enthusiastic rat owners, while the 'the bad' and 'the ugly' may be magnified in the true population of pet rats in the United Kingdom.

Our study has highlighted a number of welfare concerns that need to be addressed. However, addressing them is likely to be challenging. Over a fifth of owners reported never taking their rats to the vets, who may be able to provide education about rat care. However, lack of veterinary knowledge was an issue raised by some respondents. This may reflect that as rats are classed as an exotic species and may not regularly be seen in small animal practices; veterinarians may have little training on or experience with rat health issues and good rat husbandry, especially compared with other companion species like cats and dogs. Thus, it will be important for up-to-date information on rat care and health to be disseminated to the veterinary community. Such information could potentially be gleaned from the ever-increasing literature on laboratory rat welfare. Lessons could perhaps be learnt from the approach of the Rabbit Welfare Association (https://rabbitwelfare.co.uk/rabbit-vets/) – a charity that provides rabbit-specific clinical continued professional development (CPD), maintains a list of rabbit-knowledgeable veterinarians, and provides comprehensive rabbit care guides to small animal practices. A similar organisation for rats, with experienced exotics veterinarians at the helm, would undoubtedly help to improve knowledge about rat care in the veterinary community.

It is also clear that the advice provided by the RSPCA and PDSA (accessible online) has not reached all owners, or that not all owners act upon it. For example, the RSPCA and PDSA advise against dusty substrates as bedding material and state that rats should be provided with both bedding and nesting material[16,17] – and here, we have identified that not all owners do this. Thus, it might be sensible to target those supplying pets – larger-scale breeders and pet shops. Development of concise, evidence-based and expert-reviewed guidelines, to be distributed to breeders (for example via the National Fancy Rat Society) and pet stores to share with new owners, may help to remedy the current issues. Such guidelines could also be used by veterinary professionals.

It is clear from our study that more research needs to be conducted to better understand the welfare of pet rats. In particular, our results highlighted that research is needed to investigate whether the nutritional needs of rats are being met; if left to their own devices, rats have been shown to choose less nutritious but more palatable foods sources, even though this is detrimental to their growth and health.[46] Our study also highlighted that research is needed to understand the extent to which breeders are operating responsibly. Indeed, research has identified welfare concerns within pet rabbit breeding sector.[47] The bias towards owning male rats should also be further investigated. Additionally, our survey did not collect data on the varieties of rats (e.g. dumbo, rex, pink-eyed) owned by the respondent, this would have been useful to ascertain whether any health issue was particular to a specific variety. It would be useful to investigate this in future work. Finally, the effects of typical ranging areas available to pet rats (which will vary depending on cage type, size and ability to explore outside of the cage) and the welfare benefits that might be realised by allowing rats a wider area to roam and explore, should be investigated.

To conclude, while the present survey has highlighted areas in which rat care is good (such as the strong owner-rat bond, provision of enrichment, and rat company), there are several areas that we consider to be bad (concerns about nutrition, suppliers and a lack of opportunities to explore, possible lack of nesting opportunities) and even "ugly" (exposure to predators, and prevalence of preventable diseases). Given that these results likely represent a best-case scenario, there remains much cause for concern about the welfare of pet rats in the United Kingdom.

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ORCID

Vikki Neville https://orcid.org/0000-0002-2961-1353
Livia Benato https://orcid.org/0000-0003-2399-4194

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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